Inconsistencies in Net Sedimentation Rates within the LPR RI/FS Model Framework

Presentation to EPA Region 2
LPR CPG Modeling Team
September 26, 2013

Outline

- Introduction and motivation
- Background on the LPR model framework
- Brief summary of progress to date
- Review of unresolved issues
- Proposed update to the model framework
- Summary

Introduction and Motivation

- Deposition/erosion is a critical CFT mechanism
- The net deposition rate is a primary factor in the natural recovery of surface sediments
- Consider the sensitivity of the predicted 0-15 cm mean concentration
  - To a 1 cm/year error over a 15-year calibration simulation
  - To a 0.33 cm/year error over a 45-year projection simulation
- Shallower averaging intervals (e.g., the exposure depth within a bioaccumulation model) would be even more sensitive
- Problem:
  - The net deposition rates calculated by the CFT model differ from the predictions of the ST model
  - The ST model should be the final arbiter of deposition rates
  - Consequently, the LPR model framework needs to be corrected

Background on the LPR Model Framework

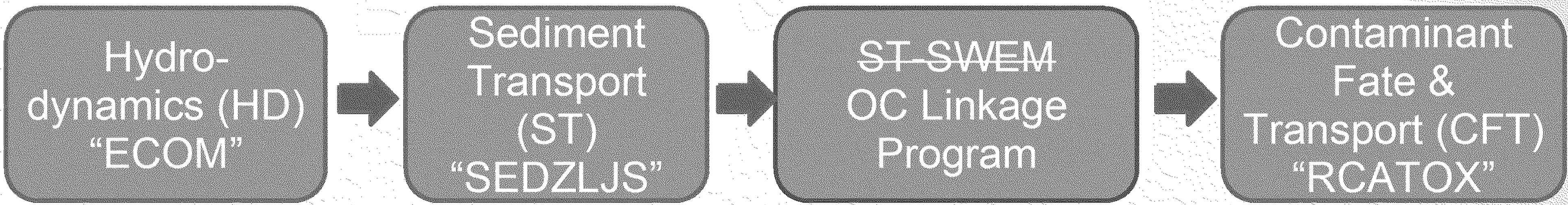
- The LPR RI/FS model is based on EPA/HQI's CARP framework
- EPA/HQI's framework consists of coupled sub-models, as shown below

Hydro-dynamics (HD) "ECOM" → Sediment Transport (ST) "SEDZLJS" → Organic Carbon (OC) "ST-SWEM" → Contaminant Fate & Transport (CFT) "RCATOX"

- Sub-models communicate via "coupling" or "linkage" files
- The CFT model ultimately receives time series of water fluxes, solids fluxes, carbon fluxes, and bed elevation changes (i.e., net deposition rates)

Background on the LPR Model Framework

- The RI/FS model framework is modified in the organic carbon linkage step, as shown below



  - Changes have also been made to the ST and CFT sub-models

- Both the original and the modified model frameworks are subject to a mismatch in net deposition rates between the CFT model and the ST model

Brief Summary of Progress to Date

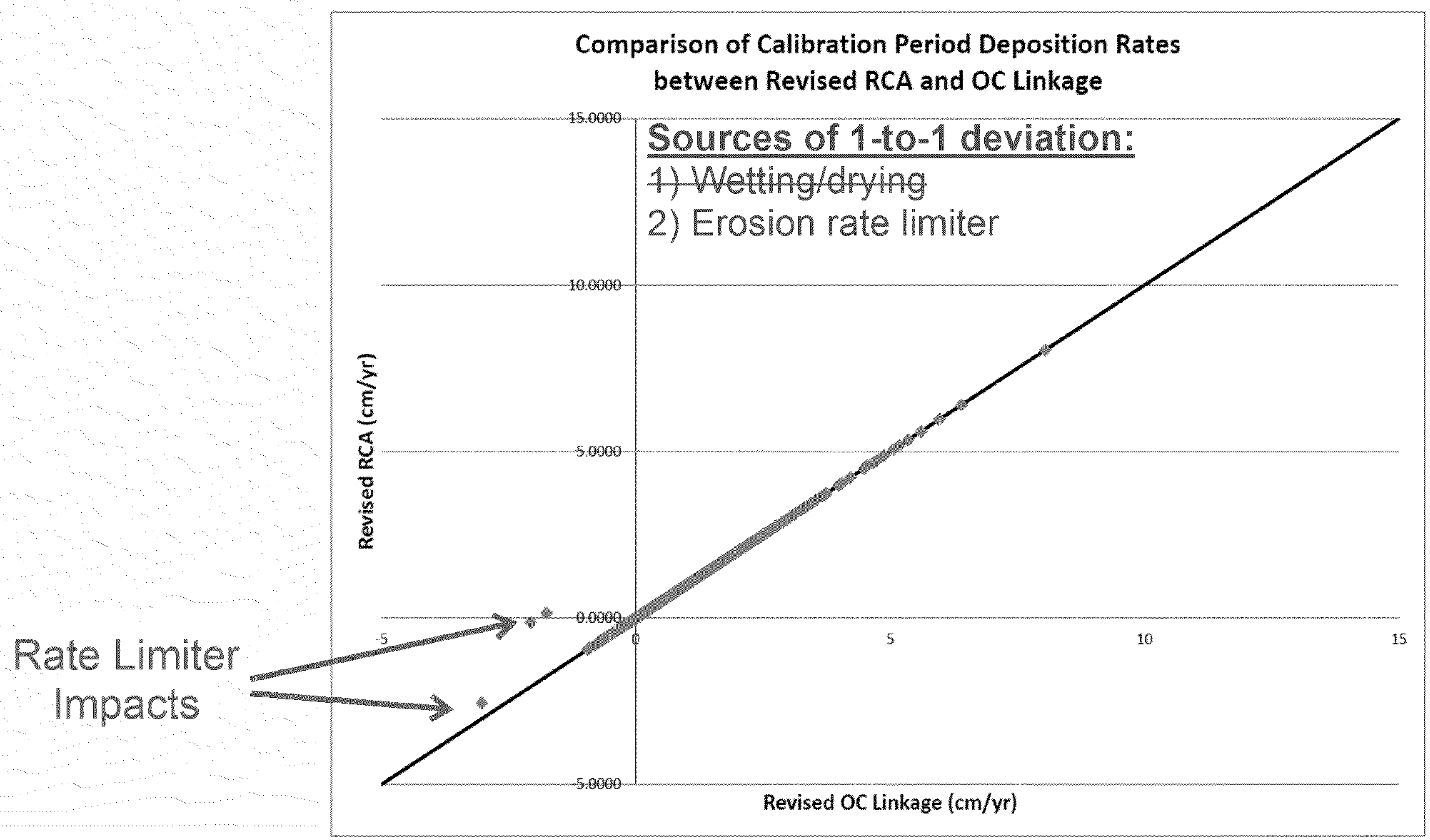
- Multiple causes of inconsistent deposition rates between sub-models have been identified
  - CPG will provide a summary table
- The CPG and EPA Modeling Teams have implemented corrections to several of these causes
  - A time-step shift in the HST coupling file (Day 15 of every year) has been corrected in ECOM-SEDZLJS
    - Impacted only decoupled HST runs
  - The ST wetting/drying logic has been made consistent with RCATOX
    - Impacted only decoupled HST runs in inter-tidal areas
  - Wetting/drying logic within RCATOX has been corrected
    - Impacted all RCATOX runs in inter-tidal areas

Brief Summary of Progress to Date

- Two unresolved issues remain, which impact all CFT runs
- **Minor issue -** The erosion rate limiter within the CFT model (for stability)
- **Major issue -** The model framework does not preserve the ST model's net deposition rates in the OC linkage step ("ST ➔ OC")
    - This is caused by differing bulk density treatment in the ST model and the OC linkage step
    - The CFT model "sees" OC linkage net deposition rates

Minor Unresolved Issue
CFT Model Erosion Rate Limiter

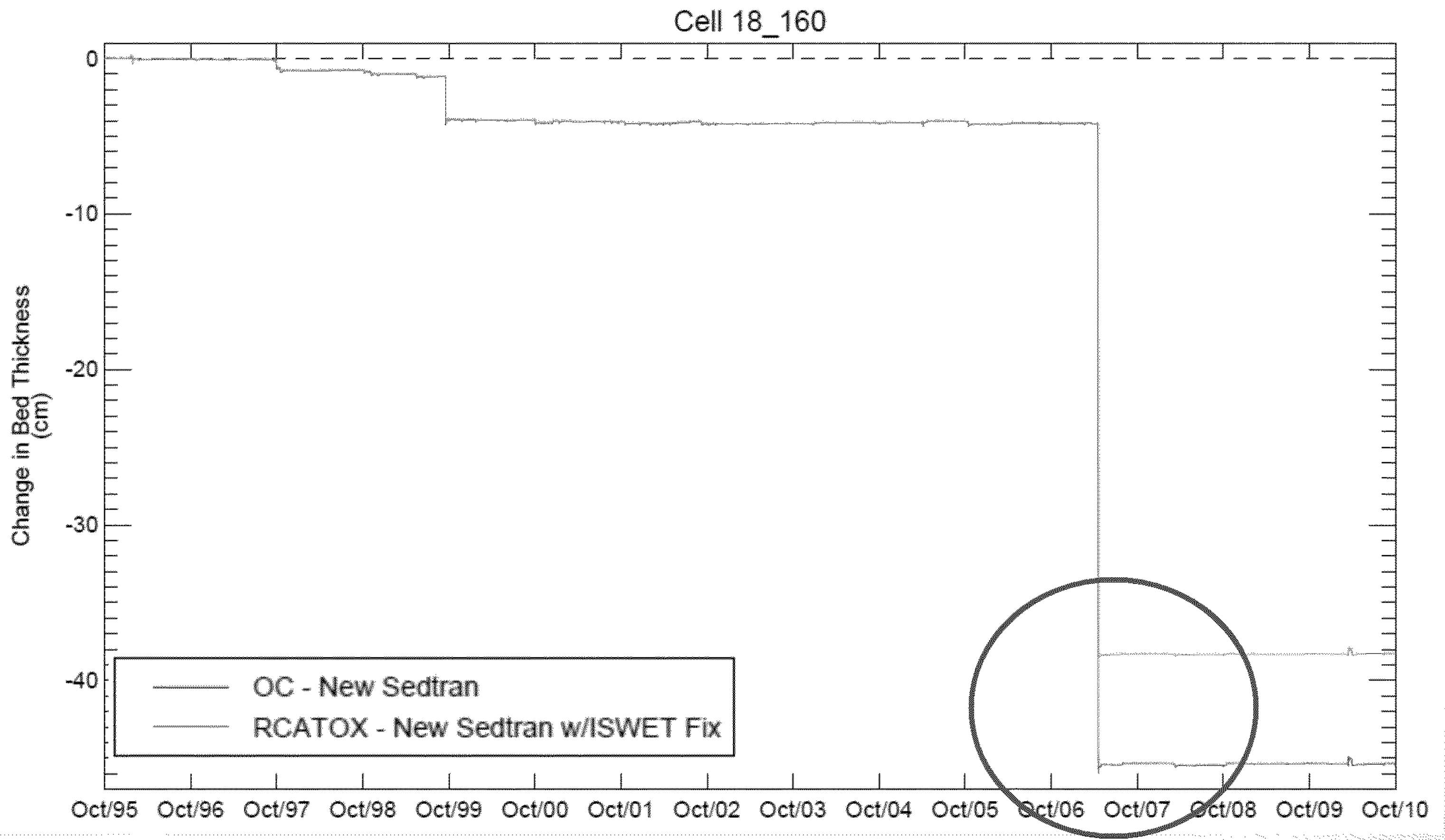
- The correction to wetting/drying behavior addresses most sources of divergence between OC linkage and RCATOX deposition rates
- Remaining divergences for 3 cells exist within the erosion rate limiter



Minor Unresolved Issue

CFT Model Erosion Rate Limiter

- The erosion rate limiter is only activated during extreme events, and only impacts select cells
- **Proposed solution:** monitor impacts and address them only as needed

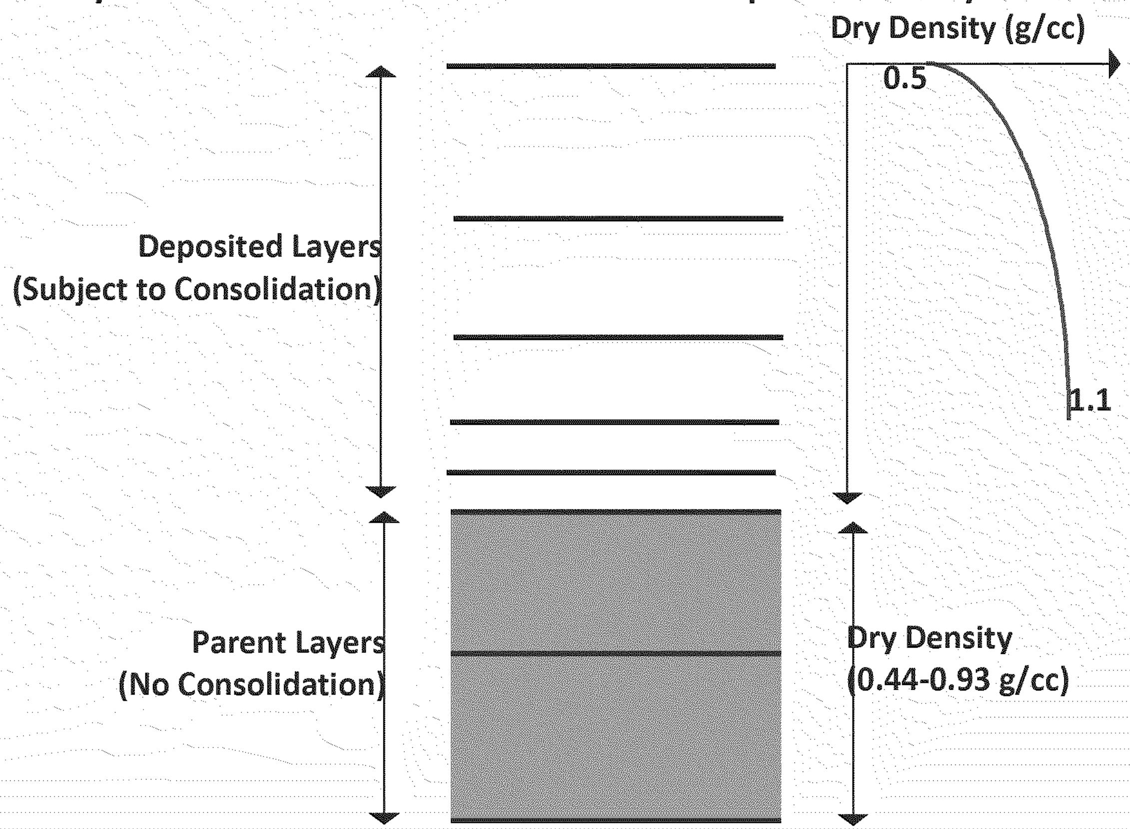


Major Unresolved Issue
ST-to-OC Net Deposition Rate Discrepancy

- **Root cause -** bulk density is treated differently in the ST and OC sub-models
  - **ST model -** bulk density varies due to bed initialization, depositional history, consolidation, and sediment type
  - **OC model -** bulk density is constant for each sediment type (cohesive and non-cohesive solids)
    - Therefore, bed bulk density is proportional to bed composition
- Consequence of differing bulk density assumptions:
  - Different net deposition rates are realized in each sub-model
  - Cells can be depositional in one case but erosional in the other
- This is a conceptual framework issue

Bed Structure – Sediment Transport Model

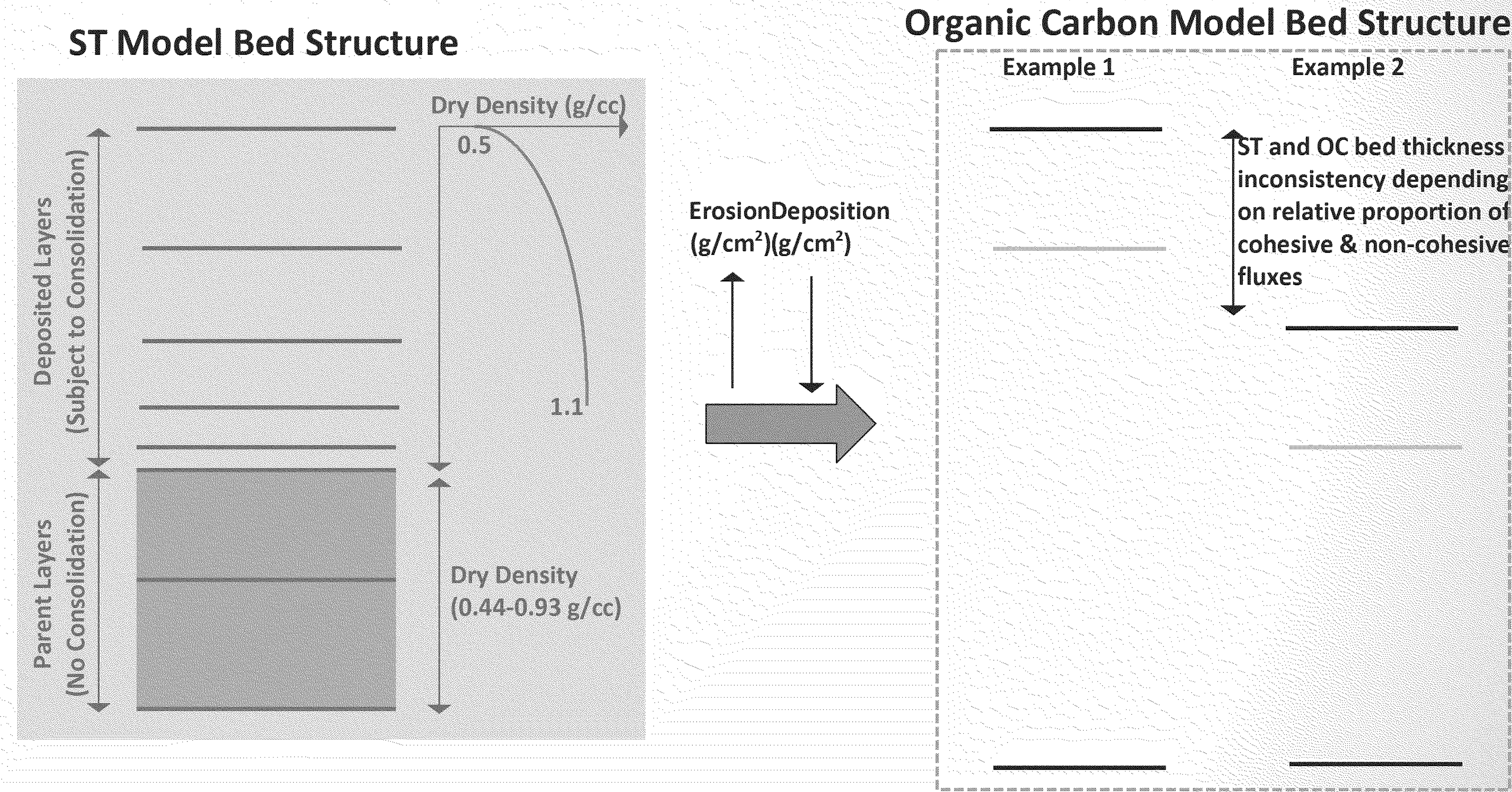
- Parent layers comprise material with which ST-model is initialized
- Deposited layers comprise material deposited during simulation
- Time-variable changes in bed thickness are computed using
  - Mass of sediments in each layer (g/cm^2)
  - Density from the consolidation model for deposited layers
  - Density from initial conditions for parent layers



Note: The ST model's dry density range is undergoing revision

ST-to-OC Linkage

- ST-to-OC linkage comprises erosion and deposition fluxes (g/cm^2)
- Bed thickness change is computed from net fluxes using dry density of 0.49 g/cm^3 for cohesives & 1.5 g/cm^3 for non-cohesives



Proposed Update to the Model Framework

- The goal is to ensure consistent net deposition rates within the LPR modeling framework
- General approach
  - ST directly passes:
    1. bed thickness changes
    2. mean bulk density (as composition) for depth averaging intervals of interest
  - Omit re-computing of the above quantities within the OC-linkage step
- Challenges include
  - Consolidation effects
  - Computational efficiency and coupling file sizes

Proposed Update to the Model Framework
Challenge - Consolidation Effects

- The ST model's bed thickness changes have two components
  - Changes due to erosion/deposition
  - Change due to consolidation
- The CFT model applies bed elevation changes from OC linkage to the CFT bed surface layer
  - This is an appropriate representation of erosion/deposition, but not of consolidation/un-consolidation
- Representing consolidation effects within the CFT model is not trivial, but consolidation is inherent to the ST model structure

Proposed Update to the Model Framework
Consolidation Effects: Proposed Solution

- The CFT model does not need to reproduce short-time consolidation effects, even though they exist within the ST model
- Do not change the ST model's internal calculations
  - Continue using time-variable consolidation/un-consolidation
- When generating linkage information, the ST model assumes **instantaneous consolidation** for passing
  - Bed thickness changes
  - Mean bulk density (composition) for averaging intervals of interest
- The CFT model continues to apply the bed elevation change directly to the sediment-water interface (i.e., the RCATOX surface bed layer)
- Benefits include
  - Extensive RCATOX modification and run-time increases are avoided
  - OC linkage file sizes should remain similar

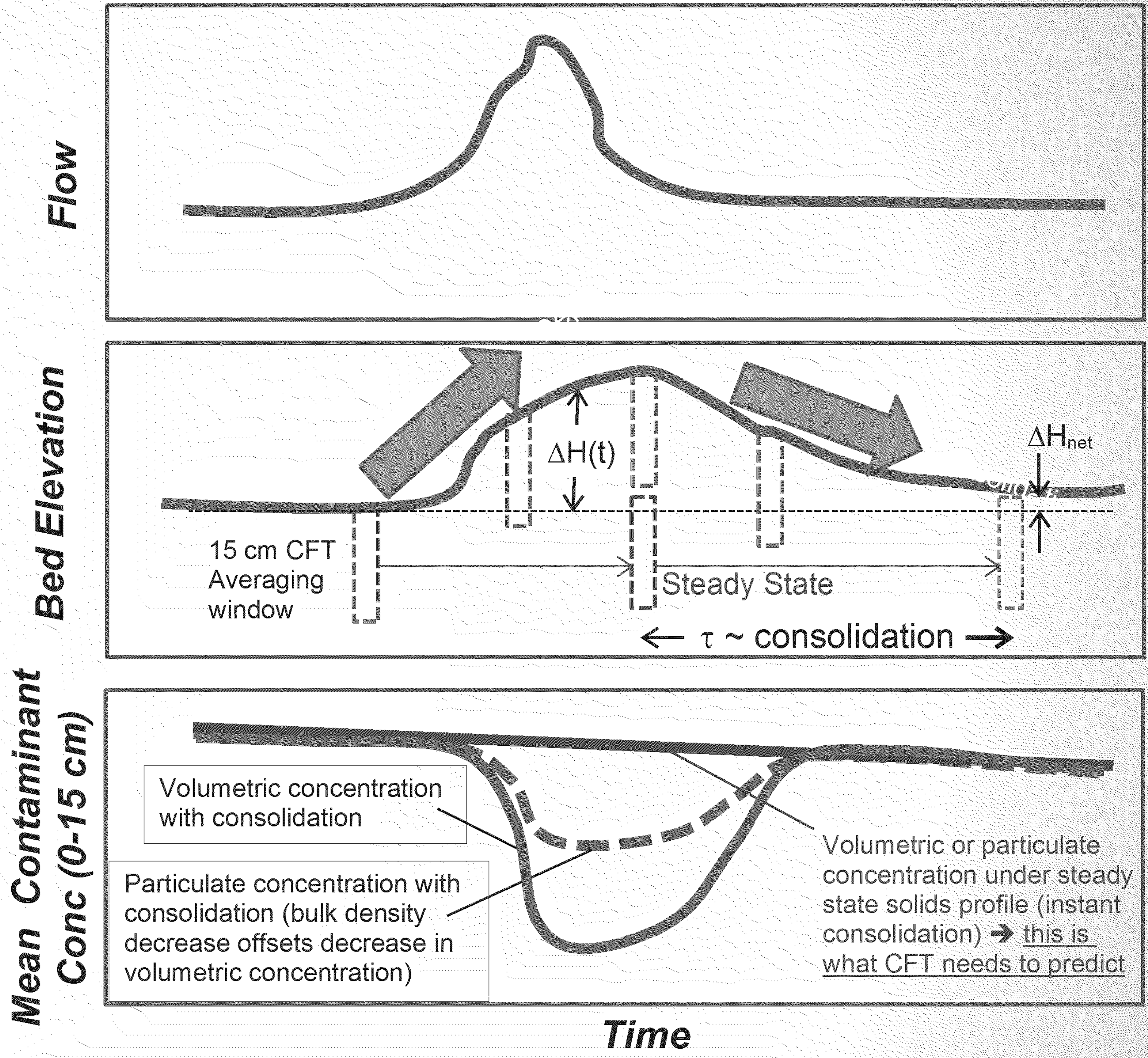
Illustration of Proposed Solution

Challenge:
Representing consolidation/un-consolidation in CFT model would be cumbersome

Solution:
CFT model "sees" only the bed elevation change and bulk density after consolidation/ un-consolidation

(steady state)

Note: The consolidation effect is exaggerated here for illustrative purposes



Summary and Status

- Deposition rate inconsistencies within the LPR model framework require several corrections to the individual sub-models and linkages
- The status for addressing contributing factors is as follows
  - Inconsistencies caused by wetting/drying have been corrected
  - Inconsistencies caused by the RCATOX erosion rate limiter are deferred due to the small number of impacted grid cells
  - Inconsistencies due to differing bulk density assumptions will be corrected
    - CPG has developed a proposed solution, subject to discussion with EPA/HQI